Water-Quality and Discharge Data for St. Joseph Bay, Florida, 1997-98

U.S. GEOLOGICAL SURVEY

Open-File Report 99-190

Prepared in cooperation with the
Florida Department of Environmental Protection

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
1999	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Water-Quality and Discharge Data for St. Joseph Bay, Florida, 1997-98	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of the Interior 1849 C Street, NW Washington, DC 20240**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**25**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Water-Quality and Discharge Data for St. Joseph Bay, Florida, 1997-98

By Marian P. Berndt and Marvin A. Franklin

U.S. GEOLOGICAL SURVEY

Open-File Report 99-190

Prepared in cooperation with the
Florida Department of Environmental Protection

Tallahassee, Florida
1999

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
Suite 3015
227 North Bronough Street
Tallahassee, FL 32301

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATIONS AND ACRONYMS

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Equations for temperature conversion between degrees Celsius (°C) and degrees Fahrenheit (°F):

°C = 5/9 (°F-32)

°F = 9/5 (°C) +32

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Acronyms and additional abbreviations used in report:

ADCP	Acoustic Doppler Current Profiler
ft/sec	feet per second
mg/L	milligrams per liter
NTUs	nephelometric turbidity units

Water-Quality and Discharge Data for St. Joseph Bay, Florida, 1997-98

By Marian P. Berndt *and* Marvin A. Franklin

Abstract

Historical data were compiled on water quality and water levels for the St. Joseph Bay area to assess quality of possible sources of land-derived water into the Bay. Ground-water quality data were compiled from Florida Department of Environmental Protection and surface-water quality data were compiled from U.S.Geological Survey files. Water-quality and water-level data were measured during two sample collection periods in October 1997 and March 1998 to determine water-quality and discharge rates in St. Joseph Bay under two sets of flow conditions. Measurements in the Bay included water level, temperature, pH, specific conductance, dissolved oxygen, and turbidity.

Median pH in water from the surficial, intermediate and Floridan aquifer systems ranged from 4.8 to 7.8, and median specific conductance values were less than 500 microsiemens per centimeter. Median nutrient concentrations--nitrate plus nitrite, ammonia and phosphorus--in the three aquifers were less than 0.5 milligrams per liter. The median pH was 7.0 and the median specific conductance was 81 microsiemens per centimeter for two samples from the Chipola River distribution canal. Water level data were obtained for several wells near St. Joseph Bay but only two wells yielded sufficient data to plot hydrographs.

Measurements in St. Joseph Bay during the October and March collection periods were similar for pH and turbidity but differed for temperature, specific conductance and dissolved oxygen. The median temperature was 20.6 degrees Celsius in October and 15.4 degrees Celsius in March, median specific conductance was 39,500 microsiemens per centimeter in October and 43,300 microsiemens per centimeter in March, and median dissolved oxygen was 7.6 milligrams per liter in October and 8.3 milligrams per liter in March. The range in water levels over a tidal cycle in St. Joseph Bay on October 29, 1997 was about 1 foot. During a 24-hour tidal cycle on October 29, 1997, estimated hourly discharge varied from about -116,000 cubic feet per second (ft^3/s) (into the Bay) to about +110,000 ft^3/s (out of the Bay). During a 24-hour tidal cycle on March 3, 1998, the water level change was about 1.3 feet and estimated hourly discharge varied from about -132,000 ft^3/s (into the Bay) to about +121,000 ft^3/s (out of the Bay).

INTRODUCTION

Fresh ground-water discharges into nearshore marine or estuarine environments can affect geochemistry of these waters and can also alter conditions for aquatic organisms. In October 1997, a study was initiated by the U.S. Geological Survey in cooperation with the Florida Geological Survey of the Florida Department of Environmental Protection to determine the general flow and quality of water in St. Joseph Bay under varying flow conditions. Results of this study will provide background information needed for an assessment of the effects of submarine ground-water discharges on the nearshore environment of St. Joseph Bay.

Purpose and Scope

The purpose of this report is to describe the historical data available for the area adjacent to St. Joseph Bay, Florida, and to describe the results of water quality, physical properties, water level and discharge measurements taken in October 1997 and March 1998. The water-quality and physical properties measured in the Bay include temperature, pH, specific conductance, dissolved oxygen, and turbidity. The geographical area covered includes St. Joseph Bay and southern Gulf County, Florida (about 5 miles inland from the Bay).

Description of the Study Area

St. Joseph Bay is located at the southern edge of Gulf County on the northwestern Gulf of Mexico coast in Florida (fig. 1). According to Rupert (1991), the Bay is "a non-estuarine lagoon formed between St. Joseph Spit and mainland Gulf County." The Bay is 11 miles long and ranges from 3 to 5 miles in width. Water depths range from less than 2 meters at the southern, closed end to approximately 10 meters near the northern end (Rupert, 1991, p.10).

Because no streams directly discharge to the Bay, the main freshwater input is presumed to be from the Gulf County Canal, precipitation, and discharge from the underlying confined Upper Floridan aquifer and adjacent shallow ground water, probably the surficial aquifer system. Estimates for Upper Floridan aquifer discharge rates for the St. Joseph Bay area range from 0.5 to 2 inches per year (in/yr) (Bush and Johnston, 1988). Net precipitation, defined as the difference between precipitation and lake evaporation, for the St. Joseph Bay area are estimated between 8 and 9 in/yr (Visher and Hughes, 1975). The Gulf County Canal is approximately 5.5 miles long and links the Intracoastal Waterway to St. Joseph Bay. A major contribution to the Canal is from the city of Port St. Joe sewage treatment plant. In 1995, the annual average discharge to the Canal from the sewage treatment plant was 57 cubic feet per second (ft^3/s)—the minimum monthly average discharge was 48 ft^3/s in July and the maximum was 65 ft^3/s in (Marella, 1999).

METHODS

A boat-mounted broad band acoustic Doppler current profiler (ADCP) was used to measure discharge in St. Joseph Bay at the tip of St. Joseph Spit. The ADCP uses the Doppler effect by bouncing an ultrasonic sound pulse off small particles of sediment and other zooplankton (scatterers) that are present in the water column (Simpson and Oltmann, 1992). The Doppler effect refers to the frequency change of the transmitted sonar signal caused by the relative movement between the ADCP and the scattering material in the water column (RD Instruments, 1992). Since the scattering material is moving at the same velocity as the water, the magnitude of the Doppler effect is directly proportional to the current velocity (RD Instruments, 1992). By sampling segments of the returning sonar signal in successive time increments, the instrument measures velocities in depth cells (acoustic signals from shallow cells return to the ADCP before signals from deeper cells, thus earlier segments of the signal correspond to shallower data) (Grubbs and Pittman, 1997). The area of these depth cells is determined by the ADCP as it measures elapsed time and velocity of the boat relative to the estuary or stream bottom.

There are several limitations to the ADCP technology. The ADCP must estimate discharge measurements near the surface, bottom, and at the sides of the transect where the water is too shallow or boat placement is not possible. Also, possible measurement errors increase when the velocity of the water is minimal as in slack tide conditions. High wind and wave action also increase measurement error. Unfortunately, one or both of these conditions were present during the two sampling efforts. At times, rocking of the boat caused the meter head to come partially or completely out of the water. In October 1997, velocities were very low, thus measurement errors were very high and precluded meaningful estimation of discharge from the velocities measured. In March 1998, velocities were low but a little higher than in October, but high winds rocking the boat caused measurement errors again to be too great to estimate discharge. The measurements made with the ADCP are available for inspection at the U.S. Geological Survey Florida District Office in Tallahassee, Fla.

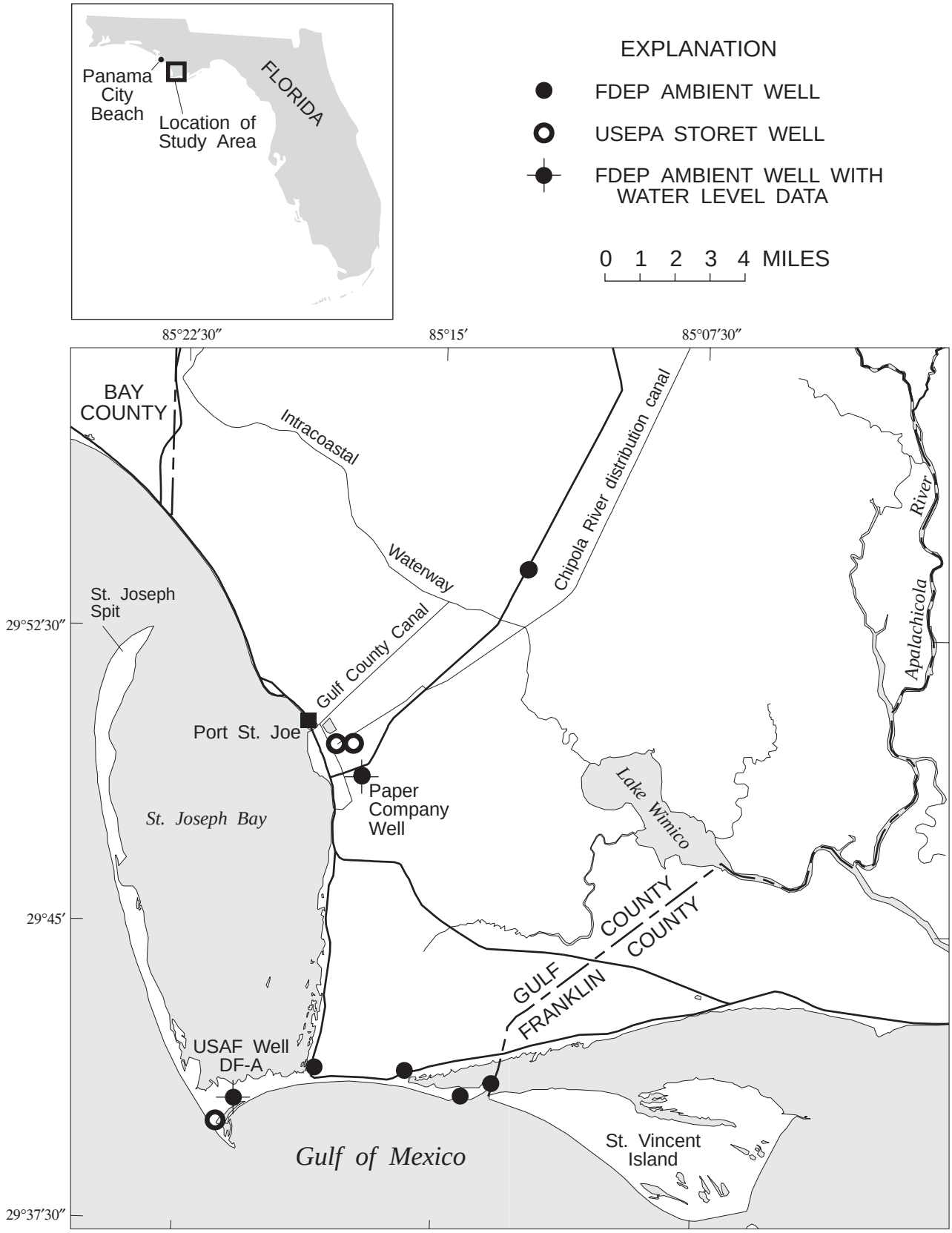

Figure 1. Location of St. Joseph Bay and wells with water-quality and water-level data.

Because of these problems with the ADCP, an alternative method was used to determine flow rates into and out of St. Joseph Bay. Discharge into and out of St. Joseph Bay were based on estimated changes in Bay volume per unit time. This was accomplished by multiplying the water level change in the Bay by the surface area of the Bay at sea level;

$$Q = \frac{dV}{dt} = A\frac{dh}{dt},$$

where

Q = discharge

$\frac{dV}{dt}$ = change in water volume in Bay per unit time

A = surface area of the Bay at sea level (approximately 1.85 X 109 square feet)

$\frac{dh}{dt}$ = change in water level per unit time

These calculations are based on the assumption that the surface area of the Bay is constant with changes in water levels. But the surface area of the Bay at water levels above sea level is probably greater than the surface area at sea level; thus discharge values based on water levels above sea level are probably slightly underestimated. Also, the surface area of the Bay at water levels below sea level is probably less than the surface area at sea level, and discharge values based on water levels below sea level are probably slightly overestimated. Wind effects and differential water buildup due to wind action could influence the accuracy of these volumetric estimates.

Stage data collected in October was compromised by placement of the temporary staff gage near heavy boat traffic. In March, the temporary gage was better positioned and reliable stage data was collected. The March stage data was compared to water levels recorded by the National Oceanic Atmospheric Administration at Panama City Beach (National Oceanic Atmospheric Administration, 1998a), the nearest site with tides similar to St. Joe Bay (U.S. Geological Survey, 1970). Water levels from Panama City Beach matched the stage data collected at St. Joseph Bay on March 3, 1998. Thus, water levels from Panama City Beach on October 29, 1997 were used to estimate discharge on October 29, 1997.

Water quality and physical properties in St. Joseph Bay were measured using multi-probe water-quality data loggers. Measurements were made from boats on October 29, 1997 and March 3, 1998. Measurements were made at selected intervals using probes lowered into the water at three depths. Descriptive and nonparametric statistics were used in this report to summarize turbidity, specific conductance, temperature and pH values and concentrations of dissolved oxygen. The nonparametric Wilcoxon rank-sum test (SAS Institute, Inc., 1990; Helsel and Hirsch, 1992) was used to test for differences in values or concentrations between data collected October 29, 1997 and data collected March 3, 1998.

HISTORICAL DATA

Water quality data were obtained from several sources. Historical ground-water quality data for Gulf County was obtained from the Florida Department of Environmental Protection's Division of Water Facilities, Ambient Monitoring Section (Florida Department of Environmental Protection, 1998). Surface-water quality data were obtained from U.S. Geological Survey water-quality data files and from USEPA STORET data (available as statistical summaries including minimum, maximum and mean). Historical data were obtained from 1974 through 1997.

Ground-Water Quality

Historical ground-water quality data were available from the three major aquifer systems in Florida, the surficial, intermediate and the Floridan. Data from the Upper Floridan aquifer was available from the Floridan aquifer system. The three aquifer systems have different natural chemical characteristics and show no signs of contamination in the data available. The data were collected from wells selected in 'background' areas; areas of known contamination were avoided (Maddox and others, 1992), so contamination is not likely to be found.

The thirty water samples from the surficial aquifer system were all collected from a single well (located in the city of Port St. Joe) that is 36 feet deep. The water is characterized by low pH (median 4.8), low dissolved solids concentration (median of 46 milligrams per liter [mg/L]) and low specific conductance (median of 41 microsiemens per centimeter (µS/cm) (table 1). The median total organic carbon concentration was 13.6 mg/L. Nutrient concentrations--nitrate plus nitrite, ammonia and phosphorus--were all low. The median ammonia concentration was the only one of the three above the detection limit.

Table 1. Summary of water quality in the surficial and intermediate aquifer systems and the Upper Floridan aquifer in Gulf County, Florida, 1986-94

[Concentrations are in milligrams per liter unless otherwise noted; °C, degrees Celsius; µS/cm, microsiemens per centimeter; --, not available]

	Surficial Aquifer System				Intermediate Aquifer System				Upper Floridan Aquifer			
	N	Median	Minimum	Maximum	N	Median	Minimum	Maximum	N	Median	Minimum	Maximum
Depth of well (feet)	1	36	36	36	7	180	70	330	7	525	338	654
Temperature (°C)	30	22.5	21	24	19	22.9	21.2	26	15	25.2	24	28.9
pH (pH units)	30	4.8	3.6	5.1	19	7.3	4.4	8.0	15	7.8	7.0	9.0
Specific conductance (µS/cm)	30	41	29	55	13	405	140	615	15	484	366	806
Dissolved oxygen	14	0.3	0.09	1.8	--	--	--	--	--	--	--	--
Dissolved solids	11	46	30	58	6	205	130	390	7	340	250	500
Bicarbonate	9	3.0	2.4	6.1	6	183	104	256	7	232	189	366
Calcium	27	.74	<.45	2.64	13	34	4.3	82	10	28	1.1	33
Magnesium	27	1	.38	1.4	13	8.3	2.2	39	10	30	2.4	46
Sodium	27	3.2	2.7	4	13	7.0	4.1	38	10	18	8.2	190
Potassium	27	.77	<1.3	1.0	13	2.4	.66	13	10	10	3.5	26
Chloride	3	3.8	3	4	6	8.8	2.5	58	7	10	5.6	38
Sulfate	3	3	<1	6.5	6	8.1	<1	49	7	8.5	<1	76
Total organic carbon	9	13.6	8.0	26.6	12	4.7	1.5	8.3	10	4.6	3.2	20.8
Nitrate + nitrite as N	24	<.02	<.02	.01	13	<.01	<.02	.05	10	<.02	<.02	.06
Ammonia as N	2	.21	.17	.26	13	.25	.02	.37	10	.36	0.2	.64
Phosphorus as P	2	<.02	<.02	<.02	13	.02	<.02	.05	10	<.02	<.02	.02

Water from the intermediate aquifer system was collected from 7 wells with depths ranging from 70 to 330 feet. The water is characterized by neutral pH (median of 7.3), median dissolved solids concentration of 205 mg/L and median specific conductance of 405 µS/cm. The median total organic carbon concentration was 4.7 mg/L. Median nitrate plus nitrite concentration was below the detection limit, median ammonia was 0.25 mg/L and the median phosphorus concentration was 0.02 mg/L.

Water samples from the Upper Floridan aquifer were collected from 7 wells with depths ranging from 338 to 654 feet. The water is characterized by neutral pH (median 7.8), median dissolved solids concentration of 340 mg/L, and median specific conductance of 484 µS/cm. The median total organic carbon concentration was 4.6 mg/L. As in the surficial aquifer system, median nitrate plus nitrite and phosphorus concentrations were below detection limits. The median ammonia concentration was 0.36 mg/L.

Surface-Water Quality

Surface-water quality data were limited in either the number of parameters reported or the number of samples taken; thus, the assessment of surface-water quality was limited. Data were available for three sampling points--St. Joseph Bay (near St. Joseph Spit), the Gulf County Canal and a distribution canal for the Chipola River (just north of the city of Port St. Joe). Although data for numerous samples were available (more than 100) for the Bay and the Gulf County Canal, only temperature, ph, dissolved oxygen, and turbidity values were reported (table 2). In contrast, only three samples were available for the distribution canal, but many water-quality constituents were measured (table 2). Mean temperatures were similar (about 23 degrees Celsius) in the Gulf County Canal and St. Joseph Bay and were about three degrees higher than the mean in the distribution canal for the Chipola River. Similarly, mean pH values in the Gulf County Canal and St. Joseph Bay were 8.2 and 8.3 mg/L, respectively, and the mean pH in the distribution canal was 7.0. No other parameters were measured at all three sites.

The mean concentrations of dissolved oxygen were similar in the Gulf County Canal and St. Joseph Bay, 7.6 and 8.3 mg/L, respectively. Mean turbidity values differed for the two sampling points, 43.4 nephelometric turbidity units (NTU's) in the Gulf County Canal and 10.9 NTU's in the Bay. The higher values in the Gulf County Canal probably reflect the proximity of the site to the land-derived sources of sediment.

In a report summarizing surface-water quality in northwestern Florida, Hand and others (1996) described the water quality in St. Joseph Bay as "essentially composed of the clear, saline waters of the Gulf of Mexico." Hand and others also state that discharges from the Port St. Joe wastewater treatment plant are diluted in St. Joseph Bay by the "good-quality bay water." In the Bay near the Gulf County Canal, however, "cloudy water has decreased seagrass coverage."

Table 2. Surface-water quality from the Chipola River distribution canal, the Gulf County Canal, and St. Joseph Bay near St. Joseph Spit

[Concentrations are in milligrams per liter unless otherwise noted. Only mean, minimum, and maxium values were available. °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU's, nephelometric turbidity units, --, not available]

	USGS station 295102085152400, Chipola River distribution canal near Port St. Joe, Florida (data from USGS files, 1975-80)				Gulf County Canal at Channel Marker 5, latitude 29°50'19", longitude 85°19'04" (data from USEPA STORET, 1990-96)				St. Joseph Bay near St. Joseph Spit, latitude 29° 49' 30", longitude 85° 24' 32" (data from USEPA STORET, 1990-96)			
	N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum
Temperature (°C)	2	20	9.0	31.0	218	23.4	10.0	33.3	224	22.9	2.9	33.9
pH (pH units)	2	7.0	6.8	7.2	120	8.2	7.3	8.6	125	8.3	7.7	8.6
Specific conductance (µS/cm)	2	81	65	97	--	--	--	--	--	--	--	--
Dissolved oxygen		--	--	--	128	7.6	2.0	10.0	132	8.3	5.3	10.0
Turbidity, NTU's		--	--	--	125	43.4	6.4	160.0	130	10.9	3.8	80.0
Bicarbonate	2	37	31	44	--	--	--	--	--	--	--	--
Calcium	3	13	9.5	39	--	--	--	--	--	--	--	--
Magnesium	3	1.5	1.4	2.7	--	--	--	--	--	--	--	--
Sodium	3	.2	0.2	0.4	--	--	--	--	--	--	--	--
Potassium	3	.9	.7	1.1	--	--	--	--	--	--	--	--
Chloride	3	4.6	3.2	8.6	--	--	--	--	--	--	--	--
Sulfate	3	<.01	<.01	.2	--	--	--	--	--	--	--	--
Total organic carbon	1	--	3.0	3.0	--	--	--	--	--	--	--	--
Nitrate + nitrite as N	2	.22	.12	.32	--	--	--	--	--	--	--	--
Ammonia as N	1	--	.04	.04	--	--	--	--	--	--	--	--
Phosphorus as P	1	--	.04	.04	--	--	--	--	--	--	--	--

Water Levels in Wells

Two wells had sufficient long-term data (multiple samples per year for more than 10 years) to construct graphs of water levels over time. One well is located in the southern edge of St. Joe Spit near Cape San Blas and the other well is located in the city of Port St. Joe (fig. 1). The well near Cape San Blas, finished in the Upper Floridan aquifer, is 595 feet deep. The well in Port St. Joe is also in the Upper Floridan aquifer but the well depth is unknown.

Water levels in the well located near Cape San Blas were available from 1974 through 1990 and ranged from 9.34 to 6.11 feet above sea level (fig. 2). The minimum water level of 6.11 feet was recorded in late 1976. Precipitation records at nearby Apalachicola, Fla. (National Oceanic Atmospheric Administration, 1998b) indicate that precipitation in 1976 was about 10 inches below the long-term average.

Water levels in the well located in Port St. Joe were available from 1980 through 1990. They were usually below sea level, ranging from 0.2 feet above sea level in January 1982 to 9.25 feet below sea level in May 1981. From mid-1987 through late 1988, water levels remained relatively constant at 6.5 to 8.8 feet below sea level. Precipitation records at Apalachicola indicate that precipitation in 1987 was about 10 inches below the long-term average.

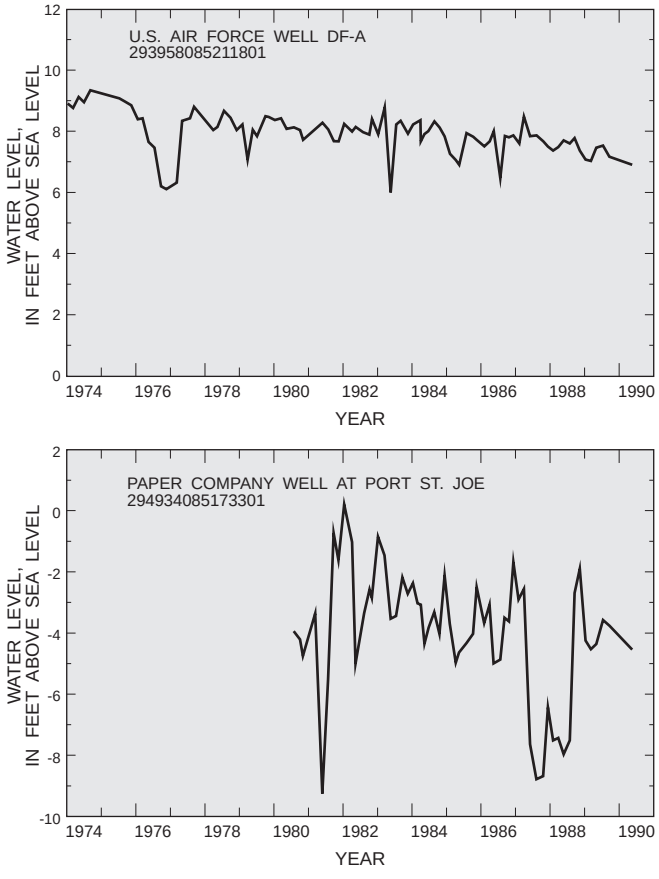

Figure 2. Hydrographs for two wells near St. Joseph Bay, 1974-90.

DISCHARGE DATA, OCTOBER 1997 AND MARCH 1998

The tidal range in St. Joseph Bay on October 29, 1997 was about 1 foot (fig. 3) (measured at Panama City Beach) (National Oceanic Atmospheric Administration, 1998a). Estimated discharge for a 24-hour tidal cycle on October 29 ranged from about -116,000 ft^3/s (into the Bay) to +110,000 ft^3/s (out of the Bay).

The tidal range in St. Joseph Bay on March 3, 1998 was about 1.3 feet (fig. 3). Estimated discharge for the 24-hour tidal cycle on March 3 ranged from about -132,000 ft^3/s (into the Bay) to about +121,000 ft^3/s (out of the Bay). During the incoming tide, flow rates in the Gulf County Canal averaged about -3,000 ft^3/s (away from the Bay). Discharge measurements made on the small tributaries to the Bay during the afternoon of March 2 were on an ebb tide, and therefore were influenced by water coming out of storage. Generally, similar conditions existed during the October data collection period, except that wind was not as significant in mixing and altering water levels.

WATER-QUALITY DATA FOR ST. JOSEPH BAY, OCTOBER 1997 AND MARCH 1998

Water-quality data collected consists of temperature, pH, specific conductance, dissolved oxygen, and turbidity. Measurements were made at 60-65 sites (fig. 4) on October 29, 1997 and again on March 3-4, 1998. Data for each constituent measured at individual measuring points are listed in the appendix.

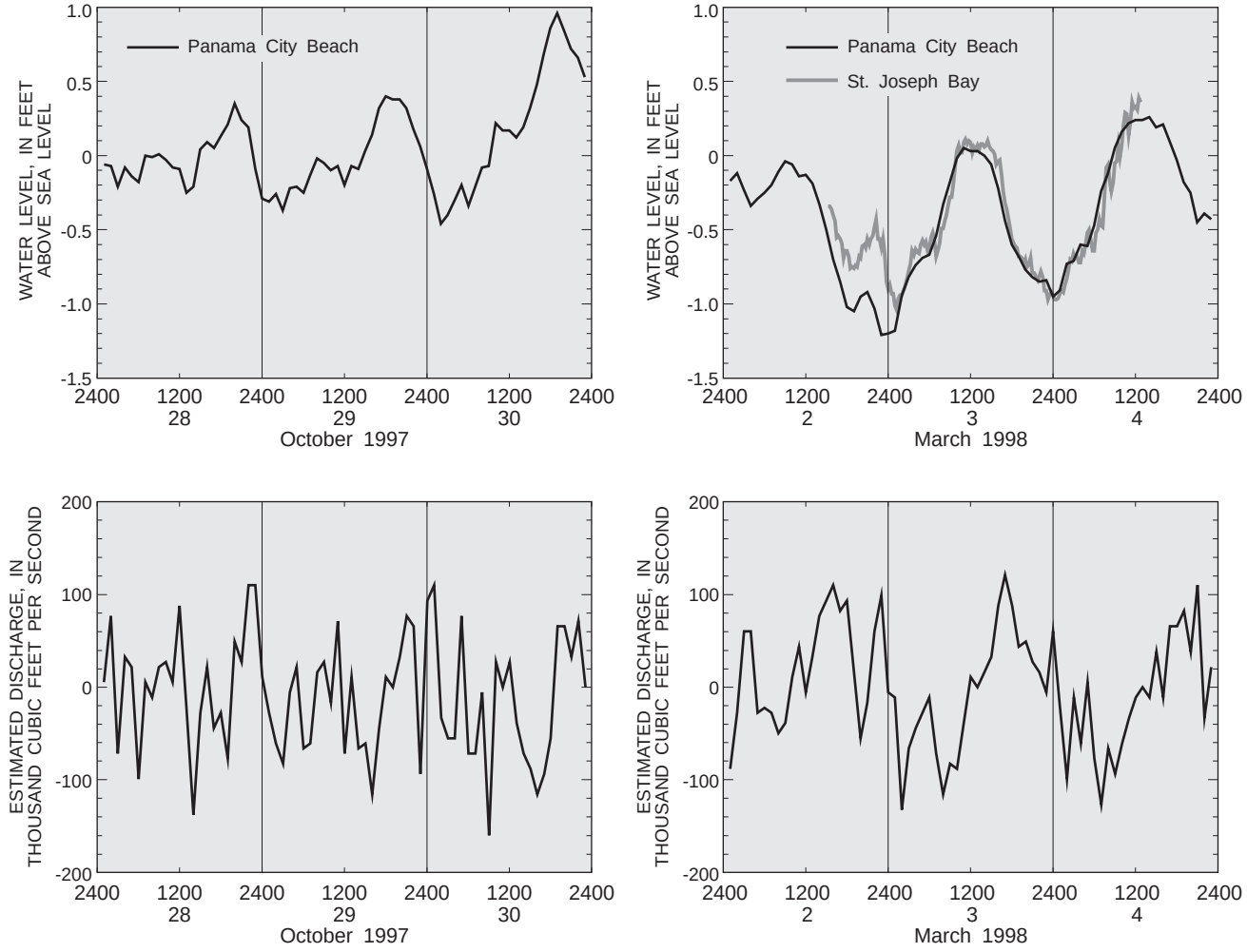

Figure 3. Gage heights for St. Joseph Bay and Panama City Beach, and estimated discharge in St. Joseph Bay for October 29, 1997 and March 3, 1998. (Panama City Beach data from National Oceanic Atmospheric Administration, 1998a.)

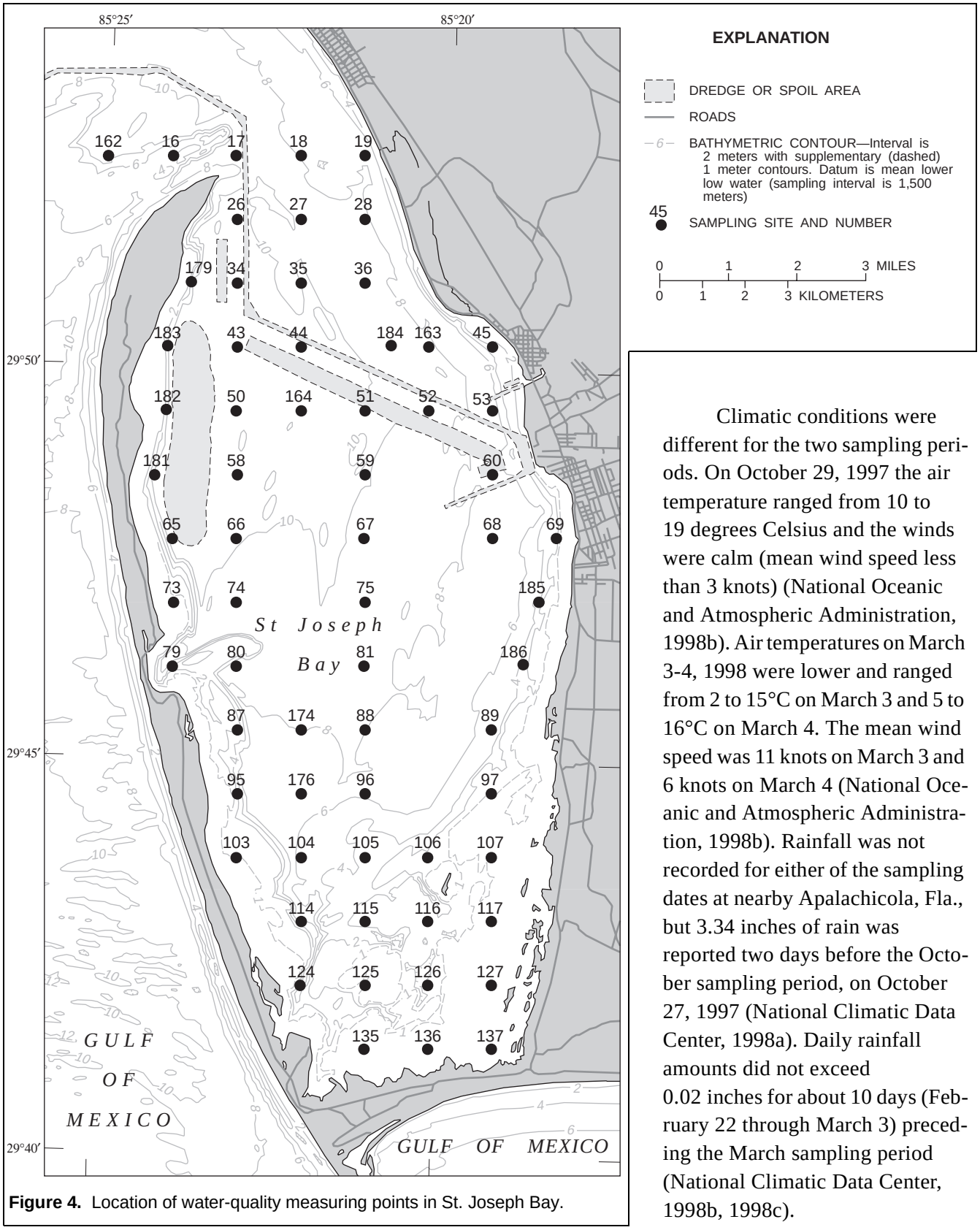

Figure 4. Location of water-quality measuring points in St. Joseph Bay.

Climatic conditions were different for the two sampling periods. On October 29, 1997 the air temperature ranged from 10 to 19 degrees Celsius and the winds were calm (mean wind speed less than 3 knots) (National Oceanic and Atmospheric Administration, 1998b). Air temperatures on March 3-4, 1998 were lower and ranged from 2 to 15°C on March 3 and 5 to 16°C on March 4. The mean wind speed was 11 knots on March 3 and 6 knots on March 4 (National Oceanic and Atmospheric Administration, 1998b). Rainfall was not recorded for either of the sampling dates at nearby Apalachicola, Fla., but 3.34 inches of rain was reported two days before the October sampling period, on October 27, 1997 (National Climatic Data Center, 1998a). Daily rainfall amounts did not exceed 0.02 inches for about 10 days (February 22 through March 3) preceding the March sampling period (National Climatic Data Center, 1998b, 1998c).

Turbidity

Turbidity is a qualitative measure of the opaqueness produced in water by suspended particulate matter (Reid and Wood, 1976). Turbidity measurements ranged from 0.1 nephelometric turbidity units to several hundred ntu's (fig. 5). In October, turbidity ranged from 0.6 to 677 ntu's, with a median of 1.3 ntu's (table 3). In March, turbidity ranged from 0.1 to 227 ntu's, with a median of 1.7 ntu's (table 3). Results of the Wilcoxon rank-sum test indicated that the difference in turbidity values betewen the October and the March data was not significant at the 0.05 significance level (p-value = 0.35). Although the medians were similar for October and March data, the distribution of the turbidity values was different, with a much larger range in values in October. This could indicate that October experienced greater land-derived inputs of water, such as runoff produced by rainfall.

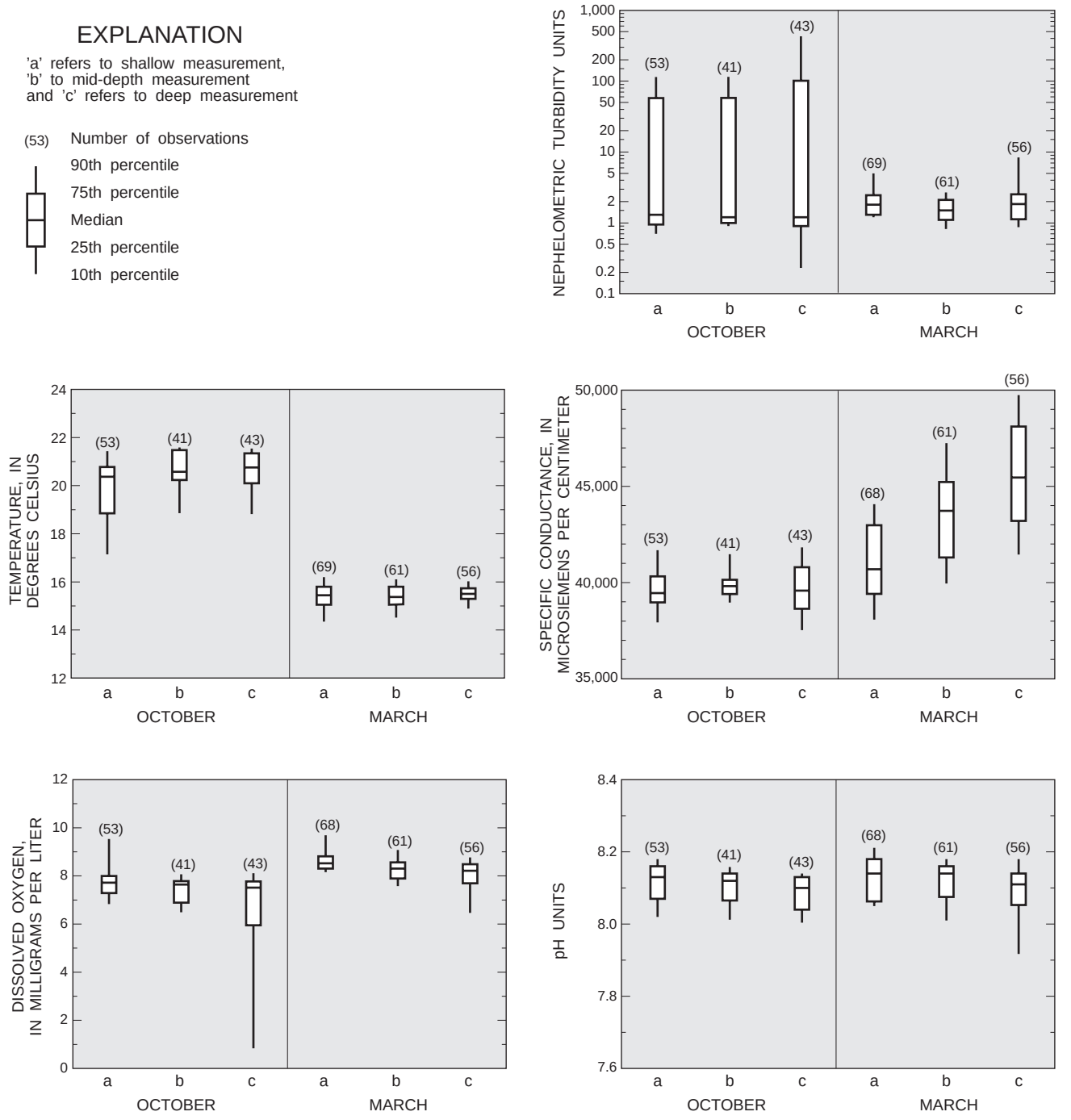

Figure 5. Turbidity, temperature, specific conductance, dissolved oxygen, and pH measurements in St. Joseph Bay, October 29, 1997 and March 3-4, 1998.

Table 3. Temperature, pH, specific conductance, dissolved oxygen, and turbidity in St. Joseph Bay, October 29, 1997 and March 3-4, 1998

[°C, degrees Celsius; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; ntu's, nephelometric turbidity units]

	October 29, 1997				March 3-4, 1998			
	N	Median	Minimum	Maximum	N	Median	Minimum	Maximum
Temperature, °C	137	20.6	16.4	22.0	255	15.4	12.7	16.7
pH, units	137	8.1	8.1	8.3	255	8.1	7.8	8.4
Specific conductance, µS/cm	137	39,500	35,900	42,600	255	43,300	23,400	51,600
Dissolved oxygen, mg/L	137	7.6	0.24	10.1	255	8.3	5.9	11.4
Turbidity, ntu's	137	1.3	0.6	677	255	1.7	0.3	227

Turbidity values >100 ntu's were all measured in the same general area. The shallow and mid-depth values >100 ntu's were at the same 7 points near the outlet of the Gulf County Canal. Turbidity values were variable by depth but often increased then decreased.

Temperature

In October, water temperatures in St. Joseph Bay ranged from 16.4 to 22°C, with a median value of 20.6°C. Higher temperatures (greater than or equal to 20 °C) were recorded in the middle and northern parts of the Bay with values less than 20°C in the southern part. In March, temperatures ranged from 12.7 to 16.7°C, with a median of 15.4°C. Similar to the October readings, higher temperatures (greater than 15°C) were measured in the northern part of the Bay, but temperatures less than 15°C were measured in central and northwestern parts of the Bay. Results of the Wilcoxon rank-sum test indicated that the difference in temperature values between the October and the March data was significant at the 0.05 significance level (p-value < 0.01). Differences by depth were not noticeable.

Specific Conductance

In October, specific conductance ranged from 36,000 to 42,500 µS/cm, with a median of 39,500 µS/cm. In March, specific conductance was higher and ranged from 23,500 to 51,600 µS/ cm; the median of 43,300 µS/cm was greater than the maximum from October. Results of the Wilcoxon rank-sum test indicated that the difference in specific conductance values between the October and the March data was significant at the 0.05 significance level (p-value <0.01). The distribution of specific conductance varied at the two measuring times. In October, the higher values of specific conductance were measured in the southern part of the Bay and little variation was noted at the three depths measured. In March, higher values were measured in the northern part of the Bay and more high values were measured at the deeper measuring points. Differences were noted in specific conductance values by depth. At the sites where measurements were made at more than 3 depths, specific conductance increased with depth.

Comparison to data collected at estuaries throughout Florida showed that values in St. Joseph Bay are higher than most other estuaries sampled. The median for 1,439 sites statewide was 37,125 µS/cm (Friedemann and Hand, 1989).

Dissolved Oxygen

In October, dissolved oxygen concentrations ranged from 0.24 to 10.1 mg/L, with a median of 7.6 mg/L (table 3). In March, dissolved oxygen concentrations were higher and ranged from 5.9 to 11.4 mg/L, with a median of 8.3 mg/L. The ranges may appear similar, but in October, nearly 90 percent of dissolved oxygen concentrations were less than the median for the March measurements. Results of the Wilcoxon rank-sum test indicated that the difference in dissolved oxygen concentrations betewen the October and the March data was significant at the 0.05 significance level (p-value < 0.01). At the sites where measurements were made at several depths, dissolved oxygen concentrations decreased with depth.

Compared to dissolved oxygen concentrations in the Bay, dissolved oxygen concentrations in ground water from the surficial aquifer system were very low. The median for the surficial aquifer system was 0.3 mg/L. According to measurements made throughout Florida and reported by Friedemann and Hand (1989), the median dissolved oxygen for 1,658 samples from estuaries throughout the State is 6.8 mg/L, slightly lower than the median values for the measurements made in St. Joseph Bay for this study.

pH

The range of pH values in the Bay was less than 1.6 pH units in measurements from both October and March. In October, pH values ranged from 6.7 to 8.3, with a median of 8.1; over 80 percent of the pH values throughout the Bay were greater than 8.0 and less than 8.2. In March, the range of pH values—7.8 to 8.4—was slightly higher than in October, but the median, 8.1, was the same as October. Results of the Wilcoxon rank-sum test indicated that the difference in pH values between the October and the March data was not significant at the 0.05 significance level (p-value = 0.07). At most sites, pH showed no differences with depth, but at several sites pH decreased slightly with depth (less than 0.2 pH units).

The median pH values measured in the Bay are slightly higher than the medians for ground water or surface water in this area (tables 1 and 2). According to measurements made throughout Florida and reported by Friedemann and Hand (1989), the median pH value for 1,552 samples from estuaries throughout the State is 8.0, similar to the values in St. Joseph Bay.

SUMMARY

Historical and current water-level, discharge, and water-quality data were collected from St. Joseph Bay and adjacent areas in Gulf County, Florida. Historical data were obtained from 1974 through 1997. Ground-water quality data for Gulf County was obtained from the Florida Department of Environmental Protection, Ambient Monitoring Section. Water from the surficial aquifer system is characterized by median pH of 4.8 and median specific conductance of 41 microsiemens per centimeter. Water from the intermediate aquifer system and Upper Floridan aquifer were similar, with median pH values of 7.3 and 7.8, respectively, and median specific conductance of 405 and 484 microsiemens per centimeter, respectively. pH in surface-water from the Chipola River distribution canal just north of the city of Port St. Joe is similar to that of the intermediate aquifer system and the Upper Floridan aquifer; but, concentrations of most constituents are higher than in the surficial aquifer system and lower than in the intermediate aquifer system and the Upper Floridan aquifer.

Water-level and water-quality data were collected in St. Joseph Bay in two sampling collection periods, low flow on October 29, 1997 and high flow on March 2-4, 1998. Water levels in St. Joseph Bay were monitored March 2-4, 1998, but October 28-30, 1997 water levels were obtained from National Oceanic and Atmospheric Administration data for Panama City Beach. Water level changes were used to estimate hourly water discharge into and out of St. Joseph Bay on the days that water-quality measurements were made. On October 29, 1997, discharge estimates varied from about -116,000 cubic feet per second (into the Bay) to about +110,000 cubic feet per second (out of the Bay). On March 3, 1998, estimated discharge for a 24-hour tidal cycle on March 3 varied from about -132,000 ft^3/s (into the Bay) to about +121,000 ft^3/s (out of the Bay).

Median turbidity and pH values were similar in October and March. The median temperature in March (15.4 degrees Celsius) was about 5 degrees cooler than the median temperature in October (20.6 degrees Celsius). But median specific conductance in March (43,300 microsiemens per centimeter) was greater than the median in October (39,500 microsiemens per centimeter). Similarly, the median dissolved oxygen concentration in March (8.3 milligrams per liter) was greater than the median in October (7.6 milligrams per liter). Differences by depth were noted for temperature, specific conductance, and dissolved oxygen but not for pH. Specific conductance increased with depth and temperature and dissolved oxygen decreased with depth.

REFERENCES

Bush, P. W., and Johnston, R. H., 1988, Ground-water hydraulics, regional flow, and ground- water development of the Floridan aquifer system in Florida and in parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Professional Paper 1403-C, 80 p.

Florida Department of Environmental Protection, 1998, Division of Water Facilities, Ambient Monitoring Section downloaded on July 21, 1998 from the following URL: "http://www2.dep.state.fl.us/water/division/monitoring/download.htm"

Friedemann, M., and Hand, J., 1989, Typical water quality values for Florida's lakes, streams, and estuaries, Florida Department of Environmental Protection, Standards and Monitoring Section, Bureau of Surface Water Management, 23 p. plus appendix.

Grubbs, J.W. and Pittman, J.R., 1997, Application of acoustical methods for estimating water flow and constituent loads in Perdido Bay, Florida: U. S. Geological Survey Water-Resources Investigations Report 97-4101, 23 p.

Hand, Joe, Col, Jana, and Lord, Linda, 1996, 1996 Water quality assessment for the State of Florida, Technical Appendix Northwest Florida: Tallahassee, Florida Department of Environmental Protection, Bureau of Surface Water Management, 128 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier, 522 p.

Maddox, G.L., Lloyd, J.M., Scott, T.M., Upchurch, S.B., and Copeland, R., eds., 1992, Florida's Ground-Water Quality Monitoring Network Program: Background Hydrogeochemistry: Florida Geological Survey Special Publication no. 34, 364 p.

Marella, R.L., 1999, Water withdrawals, use, discharge, and trends in Florida, 1995: U. S. Geological Survey Water-Resources Investigations Report 99-4002, 90 p.

National Climatic Data Center, 1998a, Climatological data, Florida, October, 1997, Ashville, North Carolina: National Climatic Data Center, vol. 101, no. 10.

National Climatic Data Center, 1998b, Climatological data, Florida, February, 1998: Ashville, North Carolina, National Climatic Data Center, vol. 101, no. 02.

National Climatic Data Center, 1998c, Climatological data, Florida, March, 1998: Ashville, North Carolina, National Climatic Data Center, vol. 101, no. 03.

National Oceanic and Atmospheric Administration, 1998a, Hourly water levels for Panama City Beach, Florida for October 1997 and March 1998 were downloaded on September 9, 1998 from the following URL: "http://www.opsd.nos.noaa.gov/data_res.html"

National Oceanic and Atmospheric Administration, 1998b, Daily temperature data and peak wind velocity for October 1997 and March 1998 downloaded on July 29, 1998 from the following URL: "http://www.ncdc.noaa.gov/onlineprod/tfsod/climvis/main.html"

RD Instruments, 1992, Technical manual for acoustic Doppler current profilers: San Diego, California, RD Instruments.

Reid, G.K., and Wood, R.D., 1976, Ecology of inland waters and estuaries, D. Van Nostrand Company, New York, 485 p.

Rupert, F.R., 1991, Geology of Gulf County, Florida: Florida Geological Survey Bulletin 63, Tallahassee, Florida, 51 p.

SAS Institute, Inc., 1990, SAS/STAT User's guide version 6, fourth edition: Cary, North Carolina, SAS Institute, Inc., vol. 2, p. 1198-1210.

Simpson, M.R., and Oltman, R.N., 1992, Discharge-measurement system using an acoustic Doppler current profiler with applications to large rivers and estuaries: U. S. Geological Survey Open-File Report 91-487, 49 p.

U.S. Geological Survey, 1970, The national atlas of the United States of America: Washington, D.C. p. 80-81.

Visher, F.N., and Hughes, G.H., 1975, The difference between rainfall and potential evaporation in Florida (2nd ed.): Florida Bureau of Geology Map Series 32, 1 sheet.

APPENDIX

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
16	10/29/97	9:30:12	21.03	40,049	6.58	8.10	21.8	a
17	10/29/97	9:40:52	20.22	39,482	7.34	8.14	21.4	a
18	10/29/97	9:50:24	21.00	39,370	6.90	8.14	18.6	a
18	10/29/97	9:48:32	21.32	39,775	6.71	8.14	18.9	b
18	10/29/97	9:47:24	21.33	39,444	6.69	8.14	320.9	c
19	10/29/97	10:00:27	21.11	39,457	6.77	8.14	57.8	a
19	10/29/97	9:58:51	21.28	39,601	6.16	8.12	63.0	b
19	10/29/97	9:57:26	21.27	37,061	4.82	8.12	0.0	c
26	10/29/97	14:31:36	20.71	39,127	7.72	8.14	1.3	a
26	10/29/97	14:30:48	21.01	39,484	7.62	8.13	1.0	b
26	10/29/97	14:29:56	21.28	39,792	7.51	8.12	1.2	c
27	10/29/97	10:14:51	21.35	39,567	6.94	8.13	57.3	a
27	10/29/97	10:12:51	21.47	39,875	6.82	8.13	57.8	b
27	10/29/97	10:11:27	21.41	38,591	6.48	8.13	0.0	c
28	10/29/97	10:25:07	21.46	39,517	6.79	8.12	57.6	a
28	10/29/97	10:23:39	21.60	39,943	6.48	8.12	57.8	b
28	10/29/97	10:22:31	21.55	40,095	6.30	8.12	0.0	c
34	10/29/97	14:00:52	20.60	38,557	7.77	8.14	1.3	a
34	10/29/97	14:00:00	20.74	39,030	7.65	8.12	1.1	b
34	10/29/97	13:59:04	21.15	39,761	7.56	8.10	1.1	c
35	10/29/97	10:36:19	21.38	39,683	7.06	8.16	57.3	a
35	10/29/97	10:33:43	21.50	40,012	6.95	8.14	57.9	b
35	10/29/97	10:31:35	21.28	38,614	0.24	8.14	66.1	c
36	10/29/97	11:03:48	21.50	39,622	6.70	8.12	57.8	a
36	10/29/97	11:02:36	21.53	39,877	6.67	8.12	57.6	b
36	10/29/97	11:01:08	21.21	38,643	0.65	8.12	24.4	c
43	10/29/97	13:48:47	20.58	38,547	7.71	8.14	1.3	a
43	10/29/97	13:47:47	20.61	39,132	7.64	8.14	0.9	b
43	10/29/97	13:46:51	21.34	39,774	7.51	8.13	0.9	c
44	10/29/97	11:15:04	20.78	36,687	7.25	8.17	58.0	a
44	10/29/97	11:13:16	21.47	40,058	7.17	8.17	57.4	b
44	10/29/97	11:11:56	21.45	40,210	6.27	8.17	0.0	c
45	10/29/97	11:47:42	21.98	39,547	6.31	8.13	69.0	a
45	10/29/97	11:46:02	21.95	39,710	5.85	8.13	67.3	b
45	10/29/97	11:43:10	21.61	35,950	1.29	8.13	374.0	c
50	10/29/97	13:05:47	20.47	39,188	7.71	8.13	1.1	a
50	10/29/97	13:04:51	20.49	39,411	7.68	8.13	0.9	b
50	10/29/97	13:03:51	20.74	39,737	7.58	8.11	0.9	c
51	10/29/97	12:01:22	20.98	36,822	7.20	8.17	57.8	a
51	10/29/97	11:59:38	21.57	40,203	6.99	8.17	57.4	b
51	10/29/97	11:57:06	21.54	39,314	5.83	8.17	431.0	c
52	10/29/97	12:11:10	21.53	37,523	7.06	8.14	115.1	a
52	10/29/97	12:09:38	21.56	39,974	6.99	8.10	114.6	b
52	10/29/97	12:08:02	21.52	39,513	6.49	8.10	0.0	c

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
53	10/29/97	12:22:18	21.81	38,982	7.10	8.16	114.7	a
53	10/29/97	12:20:18	21.59	39,897	6.38	8.11	114.9	b
53	10/29/97	12:18:34	21.53	37,276	0.42	8.11	101.4	c
58	10/29/97	12:52:11	20.58	39,414	7.69	8.12	1.0	a
58	10/29/97	12:51:19	20.57	39,442	7.66	8.12	0.9	b
58	10/29/97	12:50:27	20.62	39,525	7.62	8.12	1.1	c
59	10/29/97	13:13:01	20.73	38,626	7.34	8.17	114.3	a
59	10/29/97	13:10:49	21.49	40,067	7.11	8.15	114.7	b
59	10/29/97	13:09:05	21.36	36,438	1.12	8.13	677.0	c
60	10/29/97	13:01:31	21.05	39,151	7.24	8.17	114.5	a
60	10/29/97	12:59:14	21.73	39,817	6.82	8.14	114.3	b
60	10/29/97	12:57:30	21.54	38,684	5.95	8.14	139.8	c
65	10/29/97	12:16:00	20.29	39,415	7.81	8.10	1.4	a
65	10/29/97	12:15:00	20.24	39,421	7.82	8.10	1.3	b
65	10/29/97	12:14:00	20.10	39,432	7.81	8.09	1.1	c
66	10/29/97	12:01:00	20.43	39,376	7.73	8.02	1.1	a
66	10/29/97	11:59:56	20.44	39,384	7.70	8.02	0.9	b
66	10/29/97	11:58:40	20.61	39,638	7.52	8.00	1.1	c
67	10/29/97	13:25:33	20.73	39,132	7.53	8.18	114.4	a
67	10/29/97	13:23:09	21.53	40,086	6.52	8.14	116.2	b
67	10/29/97	13:18:57	21.48	37,915	0.54	8.14	208.8	c
73	10/29/97	11:27:08	17.42	40,110	9.38	7.48	1.6	a
74	10/29/97	11:44:40	20.33	39,196	7.75	8.02	1.4	a
74	10/29/97	11:43:40	20.37	39,401	7.76	8.02	1.0	b
74	10/29/97	11:42:32	20.82	39,915	7.51	8.01	1.2	c
75	10/29/97	13:34:45	20.77	39,077	7.41	8.17	114.4	a
75	10/29/97	13:32:37	21.41	39,992	6.74	8.14	114.8	b
75	10/29/97	13:30:49	20.86	38,010	3.18	8.07	494.0	c
79	10/29/97	11:07:30	20.20	39,314	7.43	8.08	1.1	a
79	10/29/97	11:06:26	20.35	39,477	7.38	8.08	1.2	b
79	10/29/97	11:05:34	20.43	39,821	7.31	8.07	2.1	c
80	10/29/97	10:40:30	20.16	39,173	7.79	8.02	1.1	a
80	10/29/97	10:39:38	20.10	39,197	7.79	8.01	1.0	b
80	10/29/97	10:38:06	20.08	39,337	7.76	8.00	1.1	c
81	10/29/97	13:44:49	20.77	38,968	7.33	8.17	114.1	a
81	10/29/97	13:42:29	20.93	39,689	7.20	8.16	113.9	b
81	10/29/97	13:40:05	20.88	38,093	1.46	8.12	432.0	c
87	10/29/97	10:18:30	19.74	38,944	7.85	7.90	1.4	a
87	10/29/97	10:17:38	19.72	38,957	7.86	7.90	1.3	b
87	10/29/97	10:16:46	19.64	39,017	7.88	7.88	1.1	c
88	10/29/97	13:44:55	20.72	41,670	7.59	8.10	0.7	a
88	10/29/97	13:43:51	20.66	41,739	7.49	8.10	0.7	b
88	10/29/97	13:42:51	20.75	42,553	6.85	8.06	1.3	c
95	10/29/97	9:57:06	19.54	38,763	7.93	7.17	1.6	a
95	10/29/97	9:56:22	19.53	38,773	7.94	7.05	1.3	b

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
95	10/29/97	9:55:06	19.50	38,803	7.92	6.73	1.2	c
96	10/29/97	13:31:15	20.65	41,868	7.93	8.09	0.6	a
96	10/29/97	13:29:47	20.45	41,877	7.93	8.09	0.7	b
96	10/29/97	13:28:27	20.22	42,151	7.65	8.04	132.1	c
103	10/29/97	10:20:13	18.83	41,693	7.61	8.02	0.7	a
103	10/29/97	10:19:09	18.80	41,708	7.85	8.02	0.7	c
104	10/29/97	10:13:07	19.49	41,519	8.00	8.08	0.9	a
104	10/29/97	10:11:55	19.50	41,522	8.08	8.08	1.1	b
104	10/29/97	10:10:55	19.58	41,686	8.14	8.07	1.1	c
105	10/29/97	10:03:25	20.28	41,819	7.72	8.09	0.9	a
105	10/29/97	10:02:17	20.24	41,826	7.69	8.08	0.9	b
105	10/29/97	10:01:13	20.28	41,915	7.60	8.07	2.6	c
106	10/29/97	9:52:09	20.37	42,018	8.36	8.08	1.2	a
106	10/29/97	9:53:33	20.39	42,012	8.07	8.08	1.3	c
107	10/29/97	9:36:08	16.45	41,763	9.51	8.18	1.1	a
114	10/29/97	10:31:18	18.87	41,265	7.61	8.02	0.9	a
114	10/29/97	10:29:21	18.85	41,264	7.62	8.02	1.0	b
114	10/29/97	10:28:17	18.83	41,295	7.75	8.02	1.3	c
115	10/29/97	10:41:06	18.80	41,272	7.66	8.05	1.0	a
115	10/29/97	10:40:06	18.87	41,306	7.64	8.05	1.0	b
115	10/29/97	10:38:58	18.89	41,335	7.65	8.06	0.9	c
116	10/29/97	10:49:14	18.04	40,947	7.76	8.04	0.9	a
116	10/29/97	10:48:14	18.01	40,957	7.78	8.04	0.8	b
116	10/29/97	10:47:10	17.97	40,951	7.93	8.04	1.1	c
117	10/29/97	10:57:21	16.62	40,162	9.98	8.27	0.6	a
124	10/29/97	11:31:29	17.87	40,827	7.99	8.01	1.1	a
124	10/29/97	11:30:21	17.83	40,865	8.03	8.01	1.0	b
124	10/29/97	11:29:12	17.94	41,053	8.17	8.02	0.9	c
125	10/29/97	11:21:47	17.29	40,796	8.84	8.04	1.1	a
125	10/29/97	11:20:13	17.28	40,798	8.72	8.04	1.0	b
125	10/29/97	11:18:34	17.27	40,797	8.82	8.04	1.1	c
126	10/29/97	11:11:42	17.04	40,481	8.34	8.06	0.6	a
127	10/29/97	11:04:05	16.72	39,542	9.55	8.32	0.6	a
135	10/29/97	11:46:14	16.92	39,535	10.14	8.22	0.8	a
136	10/29/97	12:11:32	17.32	39,456	9.63	8.22	0.7	a
137	10/29/97	12:45:42	17.64	37,251	9.97	8.11	1.5	a
179	10/29/97	14:18:08	20.32	38,802	8.06	8.16	1.5	a
179	10/29/97	14:17:24	20.41	38,988	8.08	8.15	1.0	b
179	10/29/97	14:15:12	21.02	39,877	7.31	8.10	1.2	c
181	10/29/97	12:38:31	20.44	39,516	7.77	8.12	0.9	a
181	10/29/97	12:37:35	20.47	39,535	7.75	8.12	0.9	b
181	10/29/97	12:36:39	20.47	39,577	7.72	8.12	0.9	c
182	10/29/97	13:24:12	20.36	38,942	7.77	8.14	1.2	a
182	10/29/97	13:23:16	20.33	38,959	7.78	8.14	1.1	b
182	10/29/97	13:22:16	20.33	39,061	7.77	8.14	0.9	c
183	10/29/97	13:36:05	20.36	36,940	8.02	8.15	1.6	a

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
183	10/29/97	13:35:13	20.22	37,809	8.41	8.17	1.3	b
183	10/29/97	13:34:21	20.14	38,217	8.64	8.18	1.0	c
162	03/04/98	9:54:00	14.99	51,630	8.42	8.18	5.3	c
162	03/04/98	9:57:00	15.04	51,220	8.19	8.2	4.9	b
162	03/04/98	10:00:00	14.95	50,800	8.19	8.2	5.0	a
16	03/04/98	10:05:00	15.22	51,570	7.84	8.18	6.0	
16	03/04/98	10:07:00	15.32	51,370	7.68	8.18	10.0	
16	03/04/98	10:10:00	15.35	50,800	7.70	8.18	8.0	a
16	03/04/98	11:05:00	15.47	50,820	8.07	8.17	6.8	
16	03/04/98	11:06:00	15.47	50,950	7.95	8.18	8.0	
16	03/04/98	11:07:00	15.38	51,250	7.91	8.18	8.5	
16	03/04/98	11:08:00	15.32	51,380	7.89	8.18	7.0	b
16	03/04/98	11:09:00	15.26	51,520	7.84	8.18	6.6	
16	03/04/98	11:10:00	15.26	51,530	7.84	8.18	4.5	
16	03/04/98	11:11:00	15.25	51,570	7.83	8.18	6.5	c
17	03/04/98	10:18:00	14.89	46,710	8.41	8.18	3.8	c
17	03/04/98	10:20:00	14.89	44,640	8.24	8.18	2.4	b
17	03/04/98	10:23:00	14.78	38,960	8.45	8.18	2.1	a
18	03/04/98	10:28:00	15.32	51,020	8.04	8.17	9.3	
18	03/04/98	10:31:00	15.46	47,180	7.95	8.16	3.9	
18	03/04/98	10:33:00	15.44	43,690	8.20	8.18	1.1	a
18	03/04/98	10:54:00	14.87	37,240	8.72	8.17	2.6	
18	03/04/98	10:55:00	15.10	41,060	8.45	8.18	2.1	
18	03/04/98	10:56:00	15.40	43,290	8.33	8.18	1.8	
18	03/04/98	10:57:00	15.39	43,730	8.37	8.18	1.1	b
18	03/04/98	10:58:00	15.30	45,480	8.38	8.18	2.1	
18	03/04/98	10:59:00	15.40	46,690	8.26	8.17	3.5	
18	03/04/98	11:00:00	15.49	48,300	8.08	8.15	7.0	c
19	03/04/98	10:37:00	15.53	49,960	7.45	8.1	15.6	
19	03/04/98	10:39:00	15.18	45,930	7.32	8.17	2.6	b
19	03/04/98	10:41:00	15.74	43,950	8.19	8.18	1.2	a
19	03/04/98	10:43:00	15.69	43,970	8.32	8.18	1.4	
19	03/04/98	10:44:00	15.18	44,690	8.38	8.17	1.4	
19	03/04/98	10:45:00	15.15	46,280	8.17	8.15	3.7	
19	03/04/98	10:46:00	15.60	44,020	7.58	8.18	1.3	
19	03/04/98	10:47:00	15.60	49,860	7.14	8.1	15.9	
19	03/04/98	10:48:00	15.62	50,550	6.98	8.1	18.9	
19	03/04/98	10:49:00	15.00	50,690	6.80	8.1	20.5	c
26	03/04/98	11:17:00	15.26	51,060	7.72	8.18	8.8	c
26	03/04/98	11:19:00	14.97	45,250	8.04	8.18	1.5	b
26	03/04/98	11:21:00	15.13	38,660	8.37	8.18	2.1	a
27	03/04/98	11:26:00	15.52	48,600	8.11	8.12	8.5	c
27	03/04/98	11:28:00	15.27	44,770	8.15	8.17	1.2	b
27	03/04/98	11:30:00	15.71	38,330	8.41	8.17	2.1	a
42	03/03/98	13:39:00	16.06	45,110	8.73	8.14	1.5	c
42	03/03/98	13:41:00	16.18	44,980	8.63	8.14	1.3	b
42	03/03/98	13:43:00	16.20	44,930	8.61	8.15	2.7	a
34	03/03/98	13:08:00	15.60	48,220	8.22	8.11	1.1	c
34	03/03/98	13:10:00	15.80	46,340	8.30	8.14	1.4	b
34	03/03/98	13:12:00	15.85	45,990	8.49	8.14	1.4	a
35	03/03/98	13:17:00	15.74	47,600	8.27	8.11	1.3	c
35	03/03/98	13:19:00	15.87	44,810	8.33	8.16	1.6	b
35	03/03/98	13:22:00	15.91	44,750	8.57	8.16	1.6	a
36	03/03/98	13:28:00	15.91	44,760	8.71	8.14	1.4	c
36	03/03/98	13:31:00	16.20	44,160	8.60	8.16	1.8	b
36	03/03/98	13:33:00	16.22	44,160	8.67	8.16	2.0	a
181	03/04/98	11:47:00	15.45	49,700	8.02	8.13	8.3	c
181	03/04/98	11:49:00	15.20	47,480	7.86	8.14	1.6	b
181	03/04/98	11:51:00	14.81	38,320	8.32	8.18	2.3	a

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
43	03/04/98	11:39:00	15.51	49,850	7.51	8.14	9.1	c
43	03/04/98	11:41:00	15.26	47,830	7.70	8.15	2.3	b
43	03/04/98	11:43:00	14.99	40,830	8.40	8.2	1.3	a
44	03/03/98	12:51:00	15.66	47,540	8.00	8.09	0.8	c
44	03/03/98	12:54:00	15.60	44,560	8.35	8.16	1.2	b
44	03/03/98	12:56:00	15.88	44,060	8.62	8.16	1.9	a
184	03/03/98	12:18:00	15.85	47,100	8.25	8.11	0.9	c
184	03/03/98	12:20:00	16.04	44,300	8.23	8.15	1.5	b
184	03/03/98	12:22:00	16.20	43,930	8.55	8.15	2.6	a
45	03/03/98	11:47:00	16.47	43,800	8.42	8.15	2.6	c
45	03/03/98	11:50:00	16.60	43,500	8.32	8.15	2.5	b
45	03/03/98	11:52:00	16.66	43,570	8.29	8.14	2.6	a
182	03/04/98	12:04:00	15.45	48,720	6.90	8.06	2.3	c
182	03/04/98	12:06:00	15.37	48,400	6.72	8.09	1.8	b
182	03/04/98	12:08:00	14.84	39,460	7.92	8.18	1.5	a
50	03/04/98	12:12:00	14.89	47,060	8.47	8.15	0.7	c
50	03/04/98	12:14:00	14.85	45,260	8.33	8.18	0.9	b
50	03/04/98	12:16:00	15.33	41,380	8.58	8.18	0.8	a
51	03/03/98	11:17:00	15.65	49,230	7.45	8.02	0.9	c
51	03/03/98	11:19:00	15.75	45,680	7.57	8.12	0.8	b
51	03/03/98	11:21:00	15.80	42,900	8.26	8.14	2.0	a
52	03/03/98	11:27:00	15.85	45,120	8.20	8.1	1.1	c
52	03/03/98	11:29:00	15.92	44,630	8.29	8.14	1.1	b
52	03/03/98	11:32:00	16.16	38,730	8.50	8.13	2.4	a
53	03/03/98	10:38:00	16.22	40,960	8.30	8.12	2.1	a
53	03/03/98	10:40:00	16.12	43,170	8.30	8.12	1.4	b
53	03/03/98	10:42:00	16.01	43,310	8.30	8.12	1.4	c
183	03/04/98	12:29:00	15.25	48,280	7.60	8.11	1.1	c
183	03/04/98	12:31:00	15.06	47,310	7.65	8.14	0.7	b
183	03/04/98	12:33:00	15.34	41,350	8.52	8.2	1.3	a
58	03/04/98	12:21:00	15.31	47,900	7.00	8.09	2.1	c
58	03/04/98	12:23:00	15.08	46,970	7.57	8.15	0.7	b
58	03/04/98	12:25:00	15.39	41,020	8.15	8.2	1.1	a
60	03/03/98	10:48:00	16.37	35,040	8.43	8.08	4.2	a
60	03/03/98	10:49:00	16.10	43,240	8.18	8.12	1.5	b
60	03/03/98	10:52:00	15.95	43,400	8.32	8.12	1.4	c
65	03/04/98	12:36:00	14.26	43,700	9.82	8.27	36.9	c
65	03/04/98	12:38:00	14.48	44,200	9.75	8.27	2.4	b
65	03/04/98	12:40:00	15.22	41,410	8.81	8.21	1.4	a
68	03/03/98	10:15:00	15.80	39,290	8.58	8.1	2.4	a
68	03/03/98	10:16:00	16.11	42,100	8.30	8.1	2.1	b
68	03/03/98	10:18:00	16.14	43,180	8.19	8.1	1.9	c
69	03/03/98	10:22:00	15.87	39,400	8.56	8.11	2.1	a
69	03/03/98	10:24:00	15.95	40,400	8.43	8.11	2.4	b
69	03/03/98	10:26:00	16.14	43,260	8.18	8.1	2.3	c
87	03/03/98	11:30:00	15.29	41,460	8.40	8.06	1.3	c
87	03/03/98	11:32:00	15.33	41,460	8.40	8.06	1.5	b
87	03/03/98	11:34:00	15.33	41,460	8.30	8.06	1.4	a
88	03/03/98	12:09:00	15.44	44,910	7.69	8.01	2.0	c
88	03/03/98	12:11:00	15.49	44,300	7.97	8.02	1.0	
88	03/03/98	12:14:00	15.51	41,930	8.04	8.05	1.3	b
88	03/03/98	12:16:00	15.84	40,610	8.06	8.06	1.9	
88	03/03/98	12:18:00	15.92	39,830	8.13	8.06	2.0	
88	03/03/98	12:20:00	15.94	39,800	8.16	8.06	2.2	a
89	03/03/98	14:10:00	15.76	33,680	9.53	8.18	15.4	a
89	03/03/98	14:13:00	15.75	33,580	9.64	8.18	14.4	b
95	03/03/98	11:10:00	15.49	40,770	8.50	8.06	1.9	c
95	03/03/98	11:12:00	15.53	40,670	8.40	8.06	1.7	b
95	03/03/98	11:14:00	15.57	40,610	8.40	8.05	1.8	a

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
96	03/03/98	10:29:00	15.44	42,340	8.42	8.05	1.5	c
96	03/03/98	10:31:00	15.34	40,890	8.22	8.06	1.3	b
96	03/03/98	10:33:00	15.33	40,660	8.16	8.06	1.4	a
97	03/03/98	14:02:00	15.64	34,840	9.65	8.23	10.2	a
103	03/03/98	11:53:00	15.25	41,000	8.76	8.14	1.3	a
103	03/03/98	11:55:00	15.26	41,450	8.75	8.15	1.5	b
104	03/03/98	11:45:00	15.44	43,000	8.52	8.13	1.7	a
104	03/03/98	11:47:00	15.44	43,050	8.48	8.13	1.4	b
104	03/03/98	11:48:00	15.22	43,010	8.49	8.13	2.0	c
105	03/03/98	11:34:00	15.00	39,260	8.81	8.15	2.8	a
105	03/03/98	11:36:00	15.03	39,330	8.76	8.16	2.5	b
105	03/03/98	11:37:00	15.60	42,520	8.50	8.13	1.9	c
106	03/03/98	11:25:00	15.29	39,180	8.85	8.16	3.0	a
106	03/03/98	11:27:00	15.33	39,140	8.82	8.16	3.2	b
107	03/03/98	13:54:00	13.19	35,410	11.36	8.39	3.1	a
107	03/03/98	13:57:00	14.07	35,600	11.43	8.4	3.2	b
114	03/03/98	12:02:00	14.70	42,150	8.67	8.14	1.8	a
114	03/03/98	12:03:00	14.70	42,210	8.59	8.14	1.9	
114	03/03/98	12:04:00	14.75	42,220	8.55	8.14	2.1	
114	03/03/98	12:05:00	14.84	42,270	8.52	8.14	1.9	b
114	03/03/98	12:07:00	14.89	42,360	8.50	8.14	2.0	
114	03/03/98	12:08:00	14.96	42,310	8.48	8.15	2.0	
114	03/03/98	12:10:00	15.08	42,550	8.47	8.14	2.1	
114	03/03/98	12:12:00	15.05	42,600	8.49	8.15	2.2	c
115	03/03/98	12:15:00	15.46	41,080	8.83	8.16	1.8	a
115	03/03/98	12:17:00	15.49	41,160	8.82	8.16	2.1	b
115	03/03/98	12:18:00	15.51	41,240	8.81	8.16	2.1	
115	03/03/98	12:20:00	15.51	41,430	8.82	8.16	2.0	c
116	03/03/98	12:22:00	13.81	40,400	10.09	8.26	1.6	a
116	03/03/98	12:23:00	13.72	40,030	10.13	8.26	1.9	
116	03/03/98	12:25:00	13.34	39,730	9.66	8.18	2.1	
116	03/03/98	12:27:00	13.19	39,610	9.14	8.16	2.7	b
116	03/03/98	12:29:00	13.26	39,590	8.84	8.15	2.7	
116	03/03/98	12:31:00	13.32	39,600	8.84	8.17	3.0	
116	03/03/98	12:33:00	13.43	39,980	9.06	8.2	3.0	c
117	03/03/98	12:38:00	13.78	39,140	10.03	8.22	227.0	a
124	03/03/98	13:33:00	14.36	43,230	8.81	8.14	1.9	a
124	03/03/98	13:35:00	14.38	43,150	8.77	8.15	2.1	b
124	03/03/98	13:37:00	14.42	43,080	8.75	8.15	1.9	c
125	03/03/98	13:27:00	14.67	40,860	10.20	8.25	1.4	a
125	03/03/98	13:29:00	14.68	40,900	10.22	8.23	2.0	b
125	03/03/98	13:22:00	14.33	40,950	9.41	8.21	2.5	a
127	03/03/98	12:50:00	12.75	35,900	9.59	8.07	4.4	a
135	03/03/98	13:42:00	15.62	42,900	10.97	8.33	1.2	a
136	03/03/98	13:47:00	14.35	43,320	10.14	8.2	1.3	a
137	03/03/98	13:01:00	13.10	40,740	9.45	8.05	13.6	a
81	03/04/98	12:35:00	15.26	0				a
82	03/04/98	12:17:00	15.69	48,180	6.04	7.88	1.4	c
82	03/04/98	12:20:00	15.65	48,190	6.11	7.92	1.4	
82	03/04/98	12:21:00	15.12	46,810	7.26	7.98	0.8	
82	03/04/98	12:22:00	15.26	46,350	7.62	8	0.7	b
82	03/04/98	12:23:00	14.67	42,200	8.03	8.04	1.1	
82	03/04/98	12:25:00	15.39	40,310	8.30	8.06	1.3	
82	03/04/98	12:27:00	15.54	40,250	8.39	8.05	1.2	a
91	03/04/98	12:04:00	13.70	44,190	9.26	8.1	0.3	c
91	03/04/98	12:05:00	13.55	43,970	8.34	8.12	0.3	
91	03/04/98	12:06:00	14.30	42,560	9.16	8.1	0.9	b
91	03/04/98	12:07:00	15.21	40,970	8.64	8.07	0.8	a
92	03/04/98	11:43:00	15.51	47,830	6.48	7.92	1.2	c

Appendix

Site number	Date	Time	Temperature, degrees Celsius	Specific conductance microsiemens per centimeter	Dissolved oxygen, milligrams per liter	pH	Turbidity nephelometric turbidity units	Depth Category
92	03/04/98	11:47:00	15.52	47,800	6.41	7.92	1.1	
92	03/04/98	11:48:00	15.40	47,520	6.88	7.96	1.0	
92	03/04/98	11:49:00	15.34	47,180	7.16	7.98	1.0	
92	03/04/98	11:51:00	15.32	46,300	7.48	8	0.7	b
92	03/04/98	11:52:00	15.13	45,570	7.77	8.01	0.7	
92	03/04/98	11:53:00	14.50	43,620	7.86	8.02	0.9	
92	03/04/98	11:54:00	15.02	40,130	8.40	8.06	1.5	
92	03/04/98	11:56:00	15.16	40,050	8.41	8.06	1.3	
92	03/04/98	11:57:00	15.39	40,040	8.48	8.06	1.3	a
94	03/04/98	10:41:00	15.74	48,280	5.94	7.9	1.5	c
94	03/04/98	10:43:00	15.74	48,000	6.15	7.92	1.0	
94	03/04/98	10:44:00	15.60	46,570	7.58	7.98	1.0	
94	03/04/98	10:45:00	15.47	45,300	7.67	8.01	1.5	
94	03/04/98	10:46:00	15.03	44,180	7.90	8.02	1.1	b
94	03/04/98	10:47:00	15.26	44,020	7.90	8.02	0.8	
94	03/04/98	10:48:00	15.27	41,900	8.03	8.04	1.1	
94	03/04/98	10:49:00	15.12	40,190	8.26	8.05	1.4	
94	03/04/98	10:50:00	15.16	40,080	8.36	8.06	1.4	
94	03/04/98	10:51:00	15.22	40,080	8.49	8.05	1.3	a
101	03/04/98	11:26:00	15.44	47,510	6.53	7.93	2.3	c
101	03/04/98	11:27:00	15.16	46,530	7.07	7.96	1.1	
101	03/04/98	11:29:00	13.78	42,260	7.60	8	0.8	b
101	03/04/98	11:30:00	14.38	41,300	8.13	8.04	0.9	
101	03/04/98	11:31:00	14.92	40,320	8.22	8.02	0.9	a
102	03/04/98	11:07:00	15.47	47,010	6.30	7.91	3.2	c
102	03/04/98	11:08:00	15.44	46,890	6.24	7.92	2.0	
102	03/04/98	11:09:00	15.37	46,270	6.75	7.95	2.1	b
102	03/04/98	11:11:00	15.31	45,970	7.06	7.97	2.1	
102	03/04/98	11:13:00	15.10	40,090	7.32	8.04	1.5	
102	03/04/98	11:15:00	15.10	39,960	8.45	8.06	1.4	a